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ORIGINAL PAPER

Effect of stump girth and height on resprouting of *Rhododendron arboreum* following disturbance in temperate mixed broad leaved forest of Arunachal Pradesh, India

Paul Ashish • Khan Mohamed Latif • Das Ashesh Kumar

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Abstract: Sprout contribution to natural regeneration of *Rhododendron arboreum* following the tree felling for fuel wood and other purposes was studied in two disturbed sites (Paipraw and Falockchar) of *Rhododendron* forest in Arunachal Pradesh, northeast India. Cut stumps were categorized into seven girth and height classes to evaluate the effect of stump girth and height on production of sprouts. Effect of stump girth on survival of sprouts was also investigated. Results show that highest number of cut stumps is recorded in medium girth classes (50–80, 80–110, and 110–140 cm) in both Paipraw and Falockchar stands. However, density of cut stumps is higher in Paipraw (1 210 stumps·ha^{-1}) than Falockchar (1 154 stumps·ha^{-1}). Nevertheless, a little higher percentage of sprouting is recorded in Falockchar (18%) than that of Paipraw (15%). Similarly, maximum number of cut stumps is observed in the medium height classes (50–80, 80–110 and 110–140 cm) in both the sites. Cut stumps with lower girths show greater ability of sprouting than that of larger girth classes. Significant correlations are observed between stump girth and sprout number and between stump height and number of sprouts. Survival of sprouts also depends on stump girth. Survival of sprout shows significant variations between different sampling times in both the sites. Though overall sprout regeneration of *R. arboreum* is very poor, sprouts arising from lower girth classes survive well than those of higher girth classes. The findings of this investigation signify that stump sprouting is not playing much role in the natural regeneration of *R. arboreum* though it has the ability to sprout. Sprout survival is not adequate to restore a stand where indiscriminate tree felling is continued and the species may be considered as a poor coppicer. Therefore, regeneration through seeds and seedlings should be preferred over regeneration through sprouting.

Keywords: Falockchar; cut stumps; Paipraw; regeneration; *Rhododendron arboreum*; sprouting

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Paul Ashish (✉) • Khan Mohamed Latif
Department of Forestry, North Eastern Regional Institute of Science and Technology (Deemed University), Nirjuli-791 109 (Itanagar), Arunachal Pradesh, India. Email: ashishpaul1@gmail.com

Das Ashesh Kumar
Department of Ecology and Environmental Science, Assam University, Silchar-788 011, Assam, India.

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Introduction

Natural regeneration of any tree species depends on the response of seeds, performance of seedlings in varied environment, and sprouting ability of cut stumps (Barnes et al. 1998; Tripathi and Khan 2007). Sprouting of stump contributes greatly to the vegetative regeneration in logged forests and is considered as an adaptive strategy to allow the tree species to remain alive and reoccupy a site following severe disturbances (Bellingham and Sparrow 2000; Bond and Midgley 2001, 2003; McLaren and McDonald 2003; Irawan and Gruber 2004; McCreary et al. 2006; Klimesova and Klimes 2007; Tripathi and Khan 2007). Resprouting of stumps and root suckers are important modes of vegetative regeneration in broad-leaved tree species, with various sprouting capacities (Lust and Mohammady 1973). Various factors have been reported to influence the development of sprouts e.g. species, age or diameter and height of parent stumps (Johnson 1975; Hobbs and Gimingham 1984; Miller and Phillips 1984; Khan and Tripathi 1986, 1989; Bellingham et al. 1994; Imanishi et al. 2010); season (Blaisdell and Mueggler 1956; Kays et al. 1985, 1988; Malanson and Trabaud 1988; Babeux and Mauffette 1994); environmental conditions (Riba 1991; Morz et al. 1985; Forester et al. 2003); growth rate and sprout quality (Wendel 1975; Khan and Tripathi 1986, 1989) and susceptibility to decay, mortality and long-term survival of sprouts (Johnson 1977; Jones and Raynal 1987; Khan and Tripathi 1986, 1989). Furthermore, irrespective of species nature, sprouting vigour is also influenced by chopping method, intensity of harvesting and season of cut

(Hook and DeBell 1970; Williston et al. 1980; Kennedy 1982; Kays et al. 1985, 1988; Ewel 1996; Gardiner et al. 2000). Generally, better sprouting occurred on smaller diameter or young aged stumps (Blake and Raitanen 1981; Khan and Tripathi 1986; Ewel 1996; Randall et al. 2005). Concurrently, stump size is often positively related to age and aging negatively affects the sprouting (Blake 1981; MacDonald and Powell 1983; Harrington 1984; Khan and Tripathi 1986, 1989; Vesk and Westoby 2004).

The genus *Rhododendron* belongs to the family Ericaceae distributed in the high altitude regions with significant ecological and economic importance. Most of the species in Arunachal Himalaya are facing tremendous pressure due to various anthropogenic disturbances. *Rhododendron arboreum* is widely distributed in western to eastern Indian Himalaya and its adjacent regions. Deforestation, unsustainable extraction for fuel, logging, clear felling etc. have built up the pressure on existence of *R. arboreum* and as a result its population is decreasing drastically. In such circumstance, sprouting ability of a species may be an important mode of regeneration to reoccupy disturbed forest ecosystem. The main input of this investigation is to provide knowledge on sprouting ability of *R. arboreum*, which may help its regeneration and management. Therefore, the present study has been carried out in temperate mixed broad leaved forests of Tawang district of Arunachal Pradesh with the following specific objectives: (i) to examine whether *R. arboreum* has ability of sprouting, (ii) whether the stump girth and height has any effect on sprouting, (iii) whether stump girth has any effect on sprouts survival, (iv) to evaluate whether surviving sprouts are adequate to reestablish the *R. arboreum* in its habitat.

Materials and methods

Study sites

The study sites are located in Tawang district of Arunachal Pradesh, northeast India. The district lies between 27°25′ to 27°52′ N latitude and 91°16′ to 91°59′ E longitude. The district is spread over 2,172 sq. km and constitutes 2.59% of the total geographical area of the state. The total forest cover of the district is 1,218 sq. km (56.08% of the total geographical area), out of which very dense forest comprises of 78 sq. km, moderately dense forest 727 sq. km and open forest covers about 419 sq. km (FSI 2005). The average monthly rainfall was recorded between 4 mm to 500 mm while mean minimum and maximum temperature was between (-)2.5ºC to 25.5ºC. Relative humidity in the district varied from a minimum of 47% to a maximum of 80%. Two sites viz., Paipraw and Falockchar were selected to examine the sprouting ability of cut stumps and their contribution in natural regeneration of *R. arboreum*. Both the sites are classified as temperate mixed broad leaved forest. Paipraw is located under Jang circle, while Falockchar is located under Mukto circle of Tawang district (Table 1). *R. arboreum* growing in patches is the main dominant evergreen broad leaved tree species in both the sites. Associate plant species of *R. arboreum* in these study sites are illustrated in Table 2. Both the sites were considered disturbed for its excessive harvesting pressure (logging of trees for fuel). Canopy of the study sites were open; soils were coarse textured with sandy to loamy sand and pH was acidic in nature.

Table 1. Location, geology and land use history of study sites of *Rhododendron arboreum*.

District	Circle	Sites	Altitudes (m a.s.l.)	Latitude	Longitude	Geology	Land use History
Tawang	Jang	Paipraw Disturbed	2922	27°33′09.9″ N	91°57′50.2″ E	Sillimanite bearing schists, gneisses and migmatites belonging to Sela Group of rocks of Paleo-proterozoic age (SRSAC 2007).	Forest
	Mukto	Falockchar Disturbed	3170	27°32′04.4″ N	91°55′48.2″ E		Forest

Table 2. Associate plant species of *Rhododendron arboreum* in Paipraw and Falockachar disturbed sites.

Life form	Paipraw Disturbed	Falockchar Disturbed
Trees	*Acer* sp., *Betula alnoides*, *Lyonia ovalifolia*, *Michelia* sp., *Pyrus pashia*, *Rhododendron arboreum, Rhododendron barbatum*	*Betula utilis*, *Lyonia ovalifolia*, *Rhododendron arboreum*, *Rhododendron barbatum*, *Rhododendron kesangiae*
Shrubs	*Aconogonon molle*, *Berberis wallichiana*, *Daphne papyracea*, *Desmodium elegans*, *Eurya acuminata*, *Gaultheria fragrantissima*, *Indigofera dosua*, *Luculia gratissima*, *Pyrus expansa*, *Rhus javanica*, *Rubus hypargyrus*, *Spiraea canescens*, *Viburnum cylindricum*, *Viburnum mullaha*	*Aster albescens*, *Berberis wallichiana*, *Daphne papyracea*, *Eurya acuminata*, *Viburnum cylindricum*
Herbs	*Ainsliaea aptera*, *Anemone polyanthes*, *Bergenia ciliata*, *Bidens pilosa*, *Corydalis geraniifolia*, *Crawfurdia speciosa*, *Cynoglossum glochidiatum*, *Dryopteris* sp., *Eupatorium adenophorum*, *Fragaria daltoniana*, *Fragaria nubicola*, *Fragaria vesca*, *Globba multiflora*, *Halenia elliptica*, *Impatiens urticifolia*, *Imperata cylindrica*, *Pilea scripta*, *Pimpinella diversifolia*, *Potentilla nepalensis*, *Rubus calycinus*, *Rubus nepalensis*, *Selinum* sp., *Swertia chirata*, *Symplocos theifolia*, *Viola canescens*	*Aconitum ferox*, *Ainsliaea aptera*, *Anaphalis adnata*, *Anemone rivularis*, *Arisaema speciosum*, *Bergenia ciliata*, *Bidens pilosa*, *Corydalis geraniifolia*, *Crawfurdia speciosa*, *Dryopteris* sp., *Eupatorium* sp., *Fragaria nubicola*, *Fragaria vesca*, *Hypericum elodeoides*, *Impatiens urticifolia*, *Imperata cylindrica*, *Leucas lanata*, *Pilea scripta*, *Potentilla microphylla*, *Potentilla nepalensis*, *Potentilla polyphylla*, *Pouzolzia* sp., *Rubus nepalensis*, *Swertia hookeri*, *Viola canescens*

Cut stump density and sprout intensity

Fifty quadrats of 10 m x 10 m were laid randomly in each stand during March to April 2004. Cut stumps of *R. arboreum* were enumerated in each quadrat and the number of sprouted stumps was counted. Density (stumps ha^{-1}) of cut stumps was also calculated. Stump girth at the cut and height from the base were measured and categorized into seven girth and height classes

(viz., 20–50, 50–80, 80–110, 110–140, 140–170, 170–200, > 200 cm).

Effect of stump size on sprouting

To study the effect of stump girth on sprouting of *R. arboreum* in Paipraw and Falockchar disturbed stands, 105 cut stumps (20±5 cm height) of *R. arboreum* were marked during June 2004 in each of the stands having 15 stumps in each seven girth classes. Since the stumps of medium girth class (50–110 cm) were most abundant in both the stands, the stumps of medium girth class were grouped in seven height classes. To study the effect of stump height on sprouting, 15 cut stumps in each of the height classes were marked in each stand. Number of sprouts on the stumps of respective girth and height classes was recorded. Sprouts on each of the marked stumps of various girth classes were labeled with aluminum tag in June 2004 and their survival was recorded seasonally at three months interval over a period of one year. Data analysis was performed using MS Excel and Origin 7 and statistically interpreted following Zar (2004).

Results

Cut stump density and sprout intensity

Densities of cut stumps of *R. arboreum* were 1 210 ha^{-1} in Paipraw stand and 1,154 ha^{-1} in Falockchar stand. Among the total recorded cut stumps, 15% and 18% were observed sprouting in Paipraw and Falockchar, respectively (Fig. 1). Maximum number of cut stumps was recorded in medium girth classes (50–80, 80–110, and 110–140 cm) in both Paipraw and Falockchar stands. Similarly, highest number of cut stumps was also recorded in medium height classes (50–80, 80–110, and 110–140 cm) in both the study stands (Fig. 2). Average cut stump girth and height were 109 cm (ranges between 32 cm and 330 cm) and 87 cm (ranges between 20 cm and 290 cm), respectively, in Paipraw, whereas in Falockchar it was 83 cm (ranges between 30 cm and 218 cm) and 87 cm (ranges between 24 cm and 190 cm), respectively.

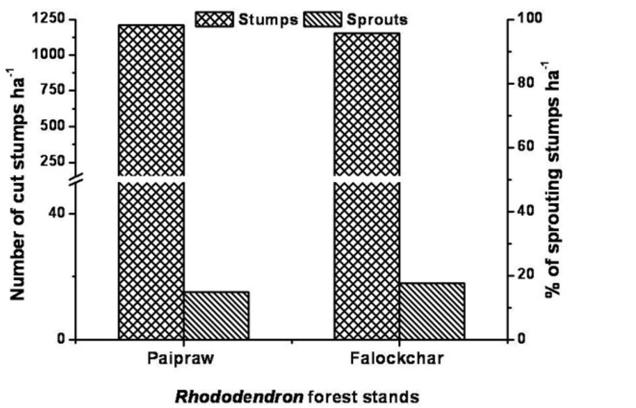

Fig. 1 Number of cut stumps and percentage of sprouting stumps in the *Rhododendron* forest stands.

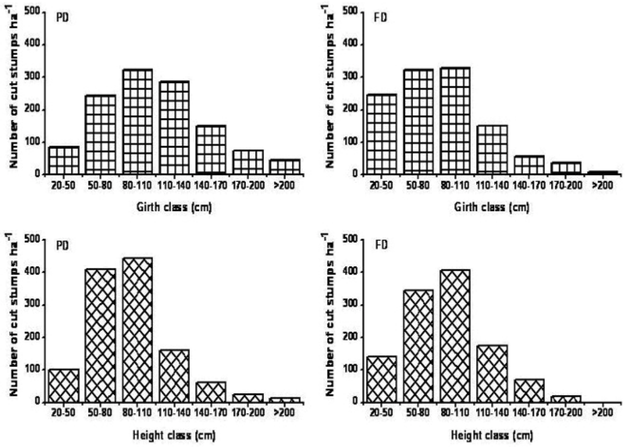

Fig. 2 Number of cut stumps in various girth and height classes of *Rhododendron arboreum* in Paipraw and Falockchar disturbed stands, PD - Paipraw Disturbed and FD - Falockchar Disturbed.

Effect of stump girth and height on sprouting

The present study revealed that the stump girth has significant effect on sprouting of *R. arboreum* in both Paipraw (r = - 0.759, p<0.001) and Falockchar (r = - 0.727, p<0.001) stands. Stumps of lower girths (20–80 cm) exhibited better sprouting than the larger girth classes at both the stands (Fig. 3). On the other hand, stump height also influenced the sprouting intensity of *R. arboreum* but the correlation was weak (Paipraw; r = 0.528, p<0.001 and Falockchar; r = 0.516, p<0.001). Maximum number of sprouts occurred on the stumps of 50–110 cm height classes in both the stands (Fig. 4). It is observed that stump girth has also impacted the survival of sprouts. Better survival was observed in sprouts arising from the stumps of lower girth classes (20–50 cm and 50–80 cm) than those of higher girth classes in both the stands. Results of one-way ANOVA exhibited that survival of sprouts varied with sampling times (Paipraw; F = 46.57, p<0.001 and Falockchar; F = 56.51, p<0.001). Survival of sprouts decreased with the increasing stump girth and time (Fig. 5).

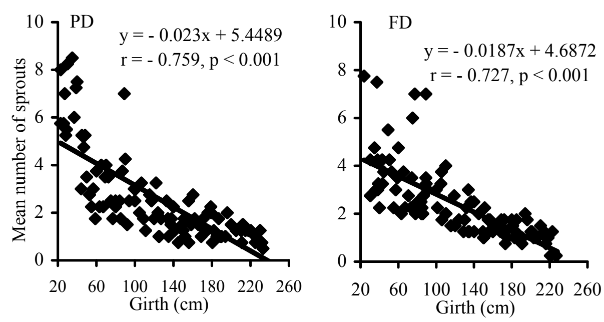

Fig. 3 Scatter plot showing the relation between girth and number of sprouts of *R. arboreum*. PD – Paipraw Disturbed and FD – Falockchar Disturbed stands.

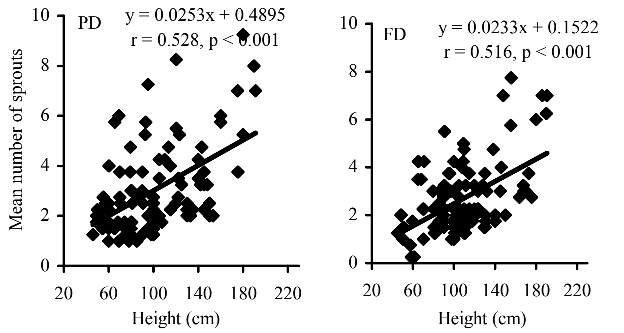

Fig. 4 Scatter plot showing the relation between height and number of sprouts of *R. arboreum*. PD – Paipraw Disturbed and FD – Falockchar Disturbed stands.

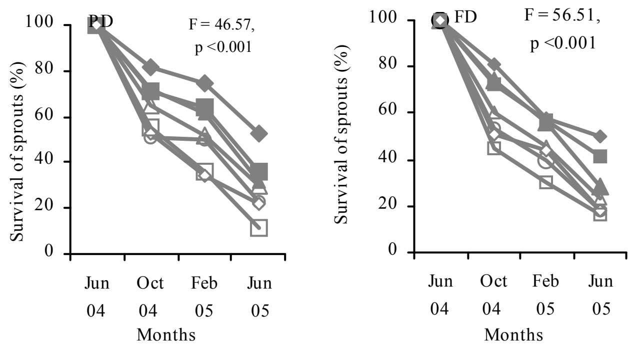

Fig. 5 Survival (%) of sprouts emerged from the stumps of different girth classes (◆ 20 – 50, ■ 50 – 80, ▲ 80 – 110, ▽ 110 – 140, ○ 140 – 170, ◇ 170 – 200, □ > 200). PD – Paipraw Disturbed and FD – Falockchar Disturbed stands.

Discussion

Results revealed that high number of cut stump is directly attributed to the extraction of *R. arboreum* for fuel. High extraction pressure on *R. arboreum* could be due to less availability of other tree species at higher elevation. Consequently, *R. arboreum* is facing tremendous pressure for existence. Density of the cut stumps was highest in medium girth classes in both the sites due to more abundant middle aged individuals in these study stands than young and very old trees. Density of cut stumps of medium heights was also recorded highest and it is attributed to the chopping convenience of local people. Results obtained from the present study indicate that majority of cut stumps did not give rise the sprouts. Less than 20% stumps produced sprouts, which may not be adequate to reestablish a new cohort of trees although it has sprouting ability. Conversely, Irawan and Gruber (2004) reported about 86% sprouting in ironwood cut stumps from Senami natural forest stand, Jambi, Indonesia. Duchok et al. (2005) also reported that cut stumps sprouting of *Illicium griffithii* ranged from 77% (undisturbed stand) to 89% (disturbed stand). Fabrick and Anderson (2000) reported 67% and 64% stump sprouting of willow and cherrybark, respectively. Furthermore, Standiford et al. (1996) found relatively high sprouting with 54% for blue oak in the northern Sacramento Valley. The poor percentage of sprouting of cut stumps of *R. arboreum* seems to be species specific. Indiscriminate chopping and decay/drying out of cut stumps could be one of the major reasons which might have reduced the sprouting abilities of *R. arboreum*.

Our findings show a negative relationship between stump girth and number of sprouts. This indicates that emergence intensity of sprouts is influenced by stump girth. Present result concurs with the findings of Mishra et al. (2003) who reported that sprouting of *R. ar1boreum* decreased with the increase in age. Results are in conformity with the findings of Johnson (1977, 1992), Oliver and Larson (1996), Weigel and Johnson (1998), and Khan and Tripathi (1986) who also observed the decrease in number of sprouts with the increase in girth/age of oak species. The result also commemorates with the findings of Khan and Tripathi (1986) who reported that sprouting percentage of the stumps and number of sprouts per stump in *Alnus nepalensis*, *Quercus dealbata*, *Quercus griffithi* and *Schima khasiana* was higher in low diameter stumps. Similarly, Ewel (1996) and Randall et al. (2005) reported that small-diameter stumps have better sprouting in *Taxodium distichum* var. *nutans*. Our results also support the findings of Keim et al. (2006) that sprouting was better on small-diameter stumps. Present observation indicates sprouting is related to stump girth size and visa-vise to age of *R. arboreum* in both the sites which is in accordance with Blake and Raitanen (1981). Blake (1981) also argued that stump size is often positively related to age and aging negatively affects sprouting. Our results also support the findings of Mattoon (1915) and Williston et al. (1980) who reported that stumps of older trees are less prolific in sprouting. During the study period it was observed that most of the extraction occurred during October to December, which may not be the favourable season to develop sprouts. This may be attributed to the fact that the species is busy with other life cycle events i.e., flower bud formation, fruit maturation, etc. Present observation confirms the findings of Buell (1940) and Kays et al. (1985, 1988) who found that plant cut during the dormant season sprout vigorously than those cut during the growing season. This observation also supports the findings of Kays and Canham (1991) who reported that cutting during growing season reduced the sprouting in *Acer rubrum*, *Betula pupulifolia*, *Fraxinus americana* and *Prunus serotina*.

Decrease in sprout numbers with increasing girth may be attributed to the physiological changes in tree species with age due to which the capability for rejuvenation by vegetative means decreases (MacDonald and Powell 1983; Putz and Brokaw 1989; Johnson 1992; Weigel and Johnson 1998; Yamada et al. 2001). In contrast, several authors have considered that sprouting ability is influenced by amount of food reserve accumulated in the stump and/or activity of underground buds. Larger stump has much amount of reserves food and/or more active underground buds as a result, bigger stump produces more sprouts (Cirne and Scarano 2001; Miura and Yamamoto 2003; Ickes et al. 2003). Our findings did not follow the above argument. Sprouts that were produced seem also to be influenced by stump height. Stump height has a positive correlation with the number of sprouts. Large number of sprouts emerged from the stumps of higher heights, which could be due to the availability of more

reserved food and more dormant buds on stumps. Similarly, Johnson (1977), MacDonald and Powell (1983), Harrington (1984), Khan and Tripathi (1986) and Mishra et al. (2003) reported that sprouting is significantly influenced by girth and height of stump.

Sprout survival decreased with the increasing stump girth in both the sites due to age of trees/stumps that lean to loose sprouting ability and have higher mortality with fatigued time. Very large and old stools lose the sprouting ability and have higher mortality of the produced shoots and become exhausted within short time (Bourgeois 1992; Imanishi et al. 2010). Survival was better on smaller stump girth due to greater withstanding ability than the higher girth size. Our result concurs with the findings of Keim et al. (2006) who reported that majority of baldcypress-water tupelo stumps/sprouts could not survive, however, smaller diameter stumps/sprouts survived better. Besides, harvesting methods, tools, and time could be the other causes for less sprout survival. Poor survival was also due to the early death of the sprouts, which agrees with the findings of Shima et al. (1989). Duchok et al. (2005) reported that cut stumps sprouting of *Illicium griffithii* was more than 85% in disturbed area, however the survival of sprouts was poor and they are frequently lopped for thin fuel wood. Hence they are not able to contribute much towards regeneration of the species. Similar is true in the case of *R. arboreum,* which showed very less spout survival.

The overall findings of this study indicate that *R. arboreum* has the sprouting ability from cut stumps; however, sprouting intensity is very poor. Less than 20% of the recorded cut stumps produced sprout. Stump girth has negative effect on sprouting, while opposite trend was observed in case of stump height. Sprout survival is also related to the stump girth. Sprouts from smaller stump girth survived better as compared to larger girth size. Findings of this research also signify that stump sprouting is not playing much role in the natural regeneration of *R. arboreum*, though it has the ability to sprout but very less as compare to the findings of many workers on other species. Sprouting and sprout survival events are not adequate to restore the harvested stand where indiscriminate extraction of wood is continued. Therefore, regeneration through seeds and seedlings should be preferred over regeneration through cut stumps although the species is very slow growing in nature. Ng and Corlett (2003) also reported that *Rhododendron simiarum* was consistent with a commitment to recruitment by seed rather than persistence by sprouting.

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